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RRE TECHNICAL NOTE

NO 700

A GENERAL PURPOSE LOW-SPEED DIAMOND SAW FOR ACCURATELY CUTTING SEMICONDUCTOR INFRA-RED AND LASER MATERIALS

BY G.W. FYNN
W.J.A. POWELL

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R.R.E. TECHNICAL NOTE NO. 700

A GENERAL-PURPOSE LOW-SPEED DIAMOND SAW FOR ACCURATELY CUTTING SEMICONDUCTOR INFRA-RED AND LASER MATERIALS

by

G. W. Fynn
W. J. A. Powell

SUMMARY

An experimental diamond saw is described which revolves at low speed. The methods used to true the blade are given. A simple micrometer-feed and damping arrangement to provide chip-free cutting of thin semiconductor blanks is an essential feature of this device. In addition to its more delicate performance, the saw is used to shape various laser-rod materials.

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5. "Talysurf" records of sawn surfaces of laser materials.

(a) Ruby
(b) Calcium Fluoride

1. INTRODUCTION

Cutting very thin semiconductor materials, has in the past proved both tedious and inaccurate: wire-saws, ultrasonic, and air-pressured abrasive methods have been tried, and, though partly successful, have not been wholly satisfactory. There appears to have been a disinclination to use a diamond wheel for sawing-up experimental quantities of semiconductor blanks - indeed, a recent publication admitted defeat at producing small I.R. detectors in this way (1). A slow-running diamond slitting saw is being successfully used at R.R.E. in an effort to improve the quality and increase the quantity of the required semiconductor devices.

Successful use of a diamond saw in this way relies on four interdependent conditions being satisfied: true running of the saw blade, both axially and radially, optimum cutting speed, cutting pressure and a suitable lubricant. This Note deals with this conditions, and gives examples of materials and dimensions of blanks that have been cut. It described the extension of the process to deal with relatively large sections of laser materials.

2. THE MACHINE

Because the initial limitation of the true running of the saw is inherent in the accuracy of its components, all turning must be concentric and all faces and shoulders square with their axes.

2.1. Base-plate (Fig. 1, Item 1)

The entire machine is mounted on an aluminium base-plate which measures approximately 9.5 in. x 6 in. x 1.5 in. (R.R.E. Pattern No. 3725).

2.2. Bearing housing (Fig. 1, Item 3)

This consists of a Dural block, slotted to clear the pulley, and line-bored to receive two ballraces - a medium duty journal race at the saw-shoulder and a light duty race at the remote end.

2.3. Saw Shaft (Fig. 1, Item 4)

2.3.1. The main requirement here is a saw-supporting cheek which must be square with the rotational axis of the shaft to minimise the axial excursion at the periphery of the saw. For this reason the shaft is centre-turned integral with the cheek.

2.3.2. To exclude end-float a small amount of axial preload is applied to the ballraces by an adjustment of the shoulder depth on the remote end-cover. Flexible washers could be used to provide the same control. Angular contact races would be preferable under axial pre-load conditions, though the journal races used in the existing models are satisfactory owing to the light duty they have to perform.

2.4. Saw disc. (Fig. 1, Item 5)

To achieve well-defined and precise diceing, a thin, 3 in. diameter diamond wheel is used and this is, of necessity, a relatively frail component, prone to damage. The larger diameter, thicker wheels in use for slicing and shaping laser rod materials, are more robust.

2.4.1. The saw disc used for precise cutting is a 'NEVEN' metal-bonded diamond wheel, nominally 0.5 ins. centre-hole, 3 ins. O.D. x 0.010 in. thick. It is located on its spigot and sandwiched between the shaft cheek and a similar free, true, cheek. It is tightened in position by a machine-cut screw and washer.

2.4.2. Two other discs are employed for rougher work - 4 in. and 5 in. diameter respectively. It is thus possible to saw material up to 1.4 in. diameter. Retaining conditions are as detailed in 2.4.1.

2.5. Drive

Different speeds are essential if a wide range of materials is to be worked. Any motor used should have this facility.

2.5.1. Drive to the saw is provided by an O-ring belt from a 1/10 B.H.P. 24 V. D. C. Motor the speed of which is controlled by varying the voltage of its power supply.

2.5.2. Any belt changing that may become necessary is effected by removing the spindle-nut and pulley locking screw and sliding the spindle out sufficiently far to carry out the change. 'GACO' O-ring belts are successful here because they are resistant to the cutting-lubricant.

3. WORKFEED MECHANISM

For performing fine-sawing operations, the Worktable must be at right angles to, and axially parallel with, the diamond wheel. It is arranged to pivot on the micrometer axis and must maintain its position throughout the subsequent cutting movement and the incremental changes made with the micrometer feed.

3.1. Micrometer Movement (Fig. 1, Item 6)

Repetition production of small semiconductor blanks accurate to 0.001 in. is accomplished by means of a simple micrometer movement, parallel to the axis of the saw. In the experimental saws, these feed-micrometers have been taken from obsolete S-band microwave cavities, but a 2 in. heavy duty micrometer could be adapted to perform this function.

3.2. Damping (Fig. 1, Item 7)

Any bumpiness in the operation of the diamond wheel tends to chip brittle semiconductor materials. The first step, therefore, is to provide a simple damping device which irons out the intermittent contact. In practice, several simple dash-pot arrangements have been tried, and, though satisfactory, these impede easy adjustment of the work table position. A simple damping-head is now in operation which gives a good buffer action.

3.2.1. The head consists of a closed cylinder containing two ballraces, free to rotate at the end of the workfeed micrometer spindle. The cavity within the cylinder is reduced to a 0.003 in. radial gap by the provision of a spacer on the shaft between the two journal ball-races. The end ball-race cover is fitted with a grease nipple.

3.2.2. A stearate grease, which has a slip-stick quality, is forced into the head-mechanism and has a light damping effect on the worktable movement.

3.3. Worktable (Fig. 1, Item 8)

There are three types of table in use, accommodating various specimen shapes and covering diverse sawing operations.

3.3.1. A general-purpose table is available for producing simple parallel cuts on boules and flat specimens. This provides a wide range of adjustment. However, because this is an unlock, set, lock device, it is dependent upon operator-skill for accuracy of setting.

3.3.2. Related angular cuts can be readily made using a turn-table top, positive movement of which is performed through a 40-1 wormgearing. A scale is provided to assist the operator to attain angular positional accuracy to better than 30 minutes.

3.3.3. Large cylindrical specimens which are cut at right angles to their axes are held in a V-Block attached directly to the Workfeed arm.

3.3.4. Cutting pressure is applied and varied by adjusting the counterweights. (Fig. 1, Item 9).

4. SAW PREPARATION

Additional preparation of the 0.010 in. wheel is often necessary when sawing 0.004 in. and 0.002 in. thick indium antimonide shapes and other brittle materials. For this reason the disc is trued at its edge, axially by controlled manipulation and radially, by a spark-erosion process.

4.1. Axial truing

The axial run-out is observed on a dial test indicator and the cutting region of the wheel is trued in situ by bending it gently. Any accidental damage to the edge of the wheel has first to be remedied by this method. The final test of the success of this manipulation is the width of slot which the disc will cut, relative to its own thickness.

4.2. Radial trueing

The wheel is trued radially in situ by spark-eroding its edge until a continuous discharge is obtained.

4.2.1. The saw is rotated at 100 r.p.m. and a cylindrical brass cathode, rotating at 200 r.p.m. and at right angles to the saw, is brought to discharge-range. A paraffin dielectric is continuously fed to the discharge-region.

4.2.2. The capacitor used for roughing is 8 μF and for fine finishing, 2 μF. The charging resistor is 220 Ω and the supply 40 volts in each case.

5. LUBRICANT

The lubricant used is a 50/50 Ethane diol/Methylated Spirit solution which does not rust steel components readily, and which is slow to dissolve pressure-sensitive adhesives. It is normally fed to the saw disc by means of a wick-feed from a reservoir (Fig. 3).

6. APPLICATIONS

In order to avoid sawing into the worktable, all specimens are mounted on glass which is in turn attached to the platform with wax. For short-duration work a pressure-sensitive adhesive can be used.

6.1 Fine Sawing

One of the requirements in the preparation of R.R.E. infra-red sensitive filaments (2) is the repetition production of rectangles of InSb accurate to 0.001 in. It was for this work that the diamond saw originally was made, since neither accuracy nor edge-definition is obtained from wire saw and air-abrasive cutting methods.

6.1.1. The semiconductor slices, 0.004 in. in thickness, are already mounted with cellulose caprate cement on plate-glass platforms before being sawn. The 0.010" wheel is used at 100-150 r.p.m. with a cutting pressure of 5 - 10 gms. Only minute edge-chipping results from this sawing method. (Fig. 4).

6.1.2. Channelled InSb detectors, prepared by preferential etching, can be resawn to provide angled ends or smaller detectors. Because the centre-section is now 0.002 in. in thickness, the surface of the detector is covered with cement at the same time as it is affixed to a glass platform. Disc rotation is 50-100 r.p.m. with a cutting pressure of 5 gms.

6.2 General-purpose sawing

An extension of the original application is the sawing of a variety of semiconductor and laser materials. For this, the larger diameter diamond saws are normally used, and relevant details are given in the table below.

Material	Depth of Cut (ins.)	Blade Dia. (ins.)	Cutting Speed (r.p.m.)	Cutting Pressure (gms.)
Indium Antimonide	.75	4	250-300	20-30
Germanium	0.25	4	250-300	20-30
Ruby	1.25	5	100-400	250
Calcium Fluoride	1.375	4	50-200	60
Calcium Tungstate	0.5	4	100	30
Neodymium-doped glass	0.5	4	200	30
Vanadium-Germanium	0.2	4	100	40
High-alumina ceramics	0.020	3	200	60

7. CONCLUSIONS

7.1. The low saw rotational speed has the following advantages:-

7.1.1. The machine is relatively easy and cheap to make under laboratory workshop conditions using only standard ball-journal races.

7.1.2. It is extremely adaptable, easy to set up and can be left unattended for the duration of a cutting operation, because of the counter-weight-fed specimen.

7.1.3. It is quiet in operation and produces neither airborne dust nor spray. It does not disturb a laboratory atmosphere.

7.1.4. There is no noticeable rise in temperature of the workpiece during operation.

7.2 The turntable can be used to orient the C-axis of a mounted ruby boule to any desired angle.

7.3 The sawn surface produced on a 1.4 in. dia. plane is flat to within ± 0.0006 in. This, combined with the relatively good surface finish (Fig. 5) makes subsequent lapping and polishing far less tedious.

8. ACKNOWLEDGMENTS

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Mr. C. Hartwright - for the design of the original saw-bearings and the execution of the diagram used herein.

Mr.H.W.Rae - for the improvement, in construction, of two subsequent models.

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2. Fynn, G.W. and Powell, W.J.A. 'The preferential etching of indium-antimonide I.R. detectors to retain thick section and the associated techniques for contact attachment'. R.R.E. Technical Note No. 684.

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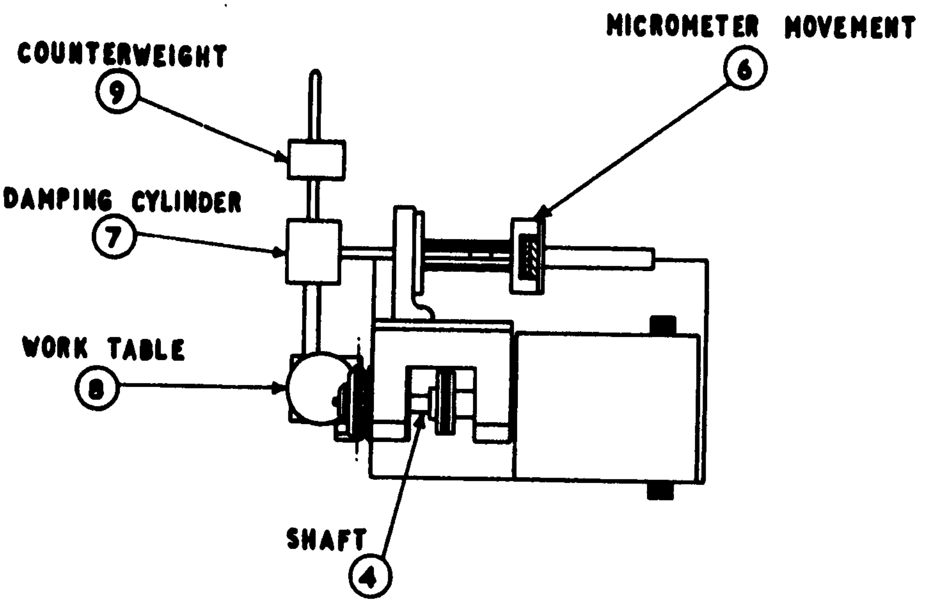


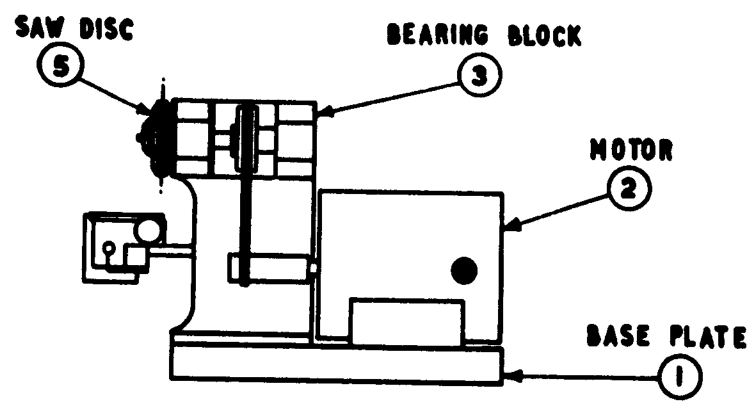


FIG. 1

DIAGRAM OF DIAMOND SAW

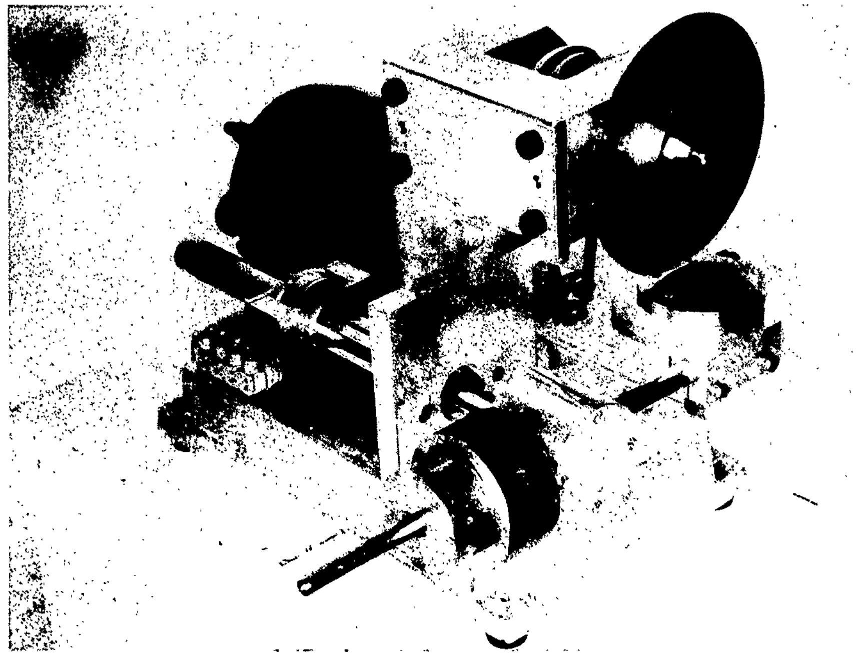


Fig 2. Photograph of saw.

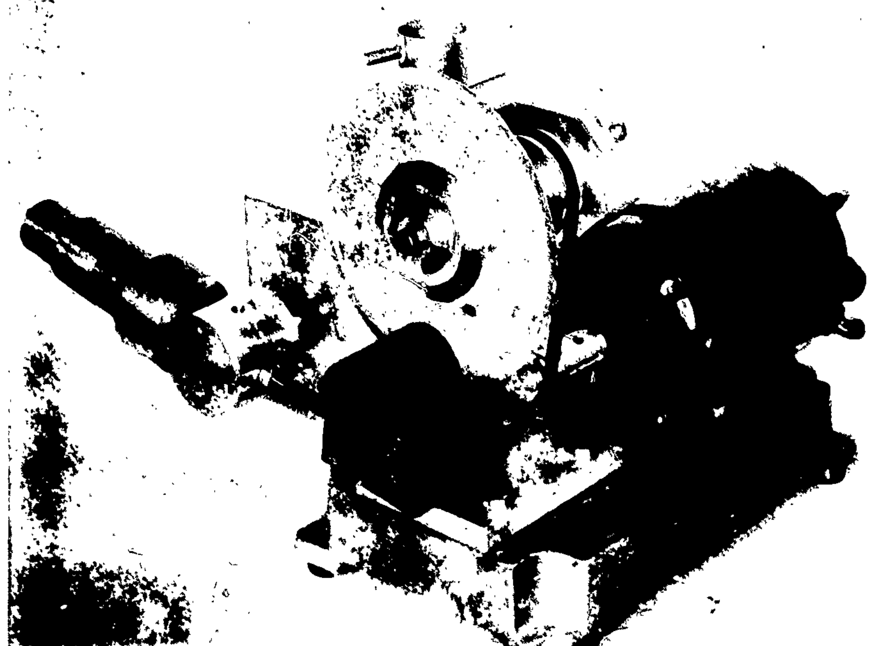
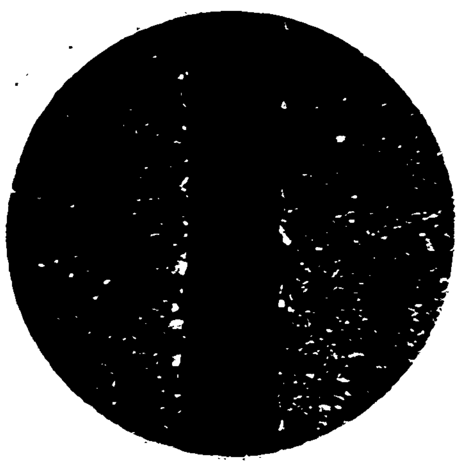
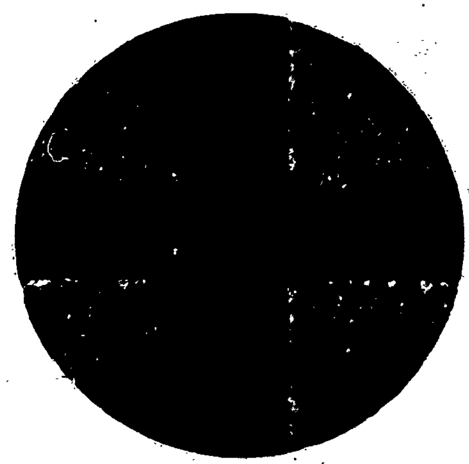


Fig 3. Saw in operation on Calcium Fluoride.

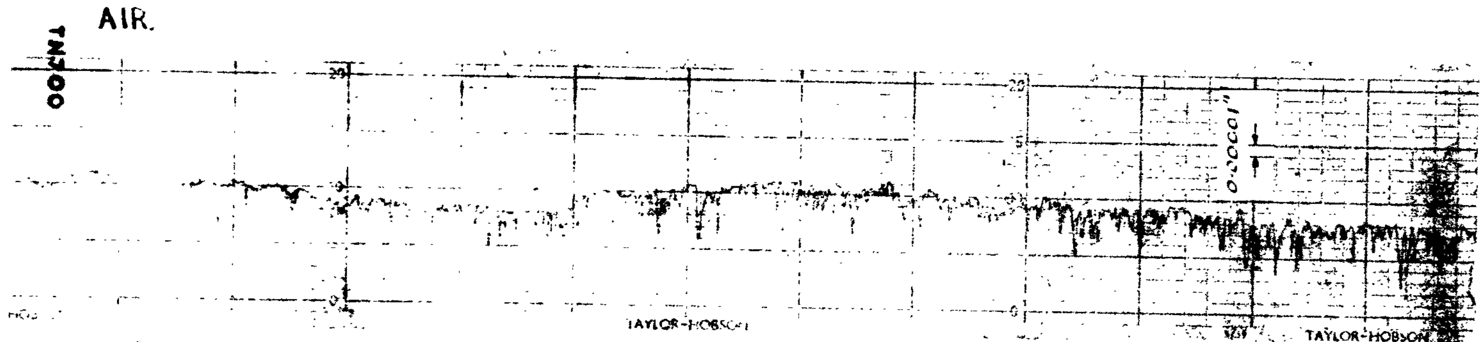


·011" Sawcut x55.



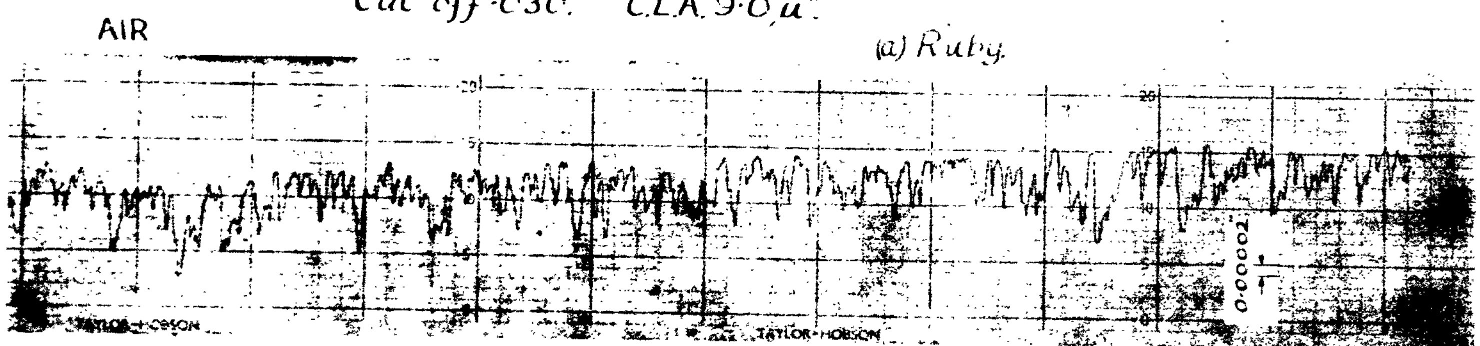
·011" Sawcut x55.

Fig. 4.



Vertical magnification 10,000. Horizontal magnification 100.
Cut off ·030". C.L.A. 9·0 μ".

(a) Ruby.



Vertical magnification 5,000. Horizontal magnification 100.
Cut off ·030". C.L.A 28 μ".

(b) Calcium Fluoride. Fig 5.

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